CHANGES IN THE ANNUAL CYCLE AND SEASONAL CHARACTERISTICS OF PRECIPITATION IN THE DANUBE RIVER LOWER BASIN

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Abstract: Precipitation is one of the main climatic elements which determines the availability of water resources and has considerable impact on different aspects of human activity. The present analysis is based on monthly precipitation totals from 22 meteorological stations situated in the Danube River lower basin both in Romania and Bulgaria. These stations have been divided into three groups by their geographical distribution and the peculiarities of the study area (western, central and eastern). The aim of this paper is to provide detailed information about the characteristics of annual and seasonal variability of precipitation in this area, focusing on annual cycle and linear trends. The investigated period is 1961-2007. To reveal the characteristics of temporal variability of precipitation, two 30-year reference periods have been considered: 1961-1990 and 1978 – 2007. In general, for the entire analyzed area and complete period 1961-2007, the annual cycle of precipitation showed June as the wettest month and February and October as the driest months. However, as regards the details on each subgroup, some changes of the annual cycle occurred between subgroups and the two reference periods. For instance, in the western subgroup, the wettest month on record is June for 1961-1990 and May for 1978 – 2007. In the central subgroup, it is still June for 1961-1990, but it is July for 1978-2007. Regarding the linear trend over 1961-2007, a decrease for the winter season was identified, which is statistically significant only at six stations. For other seasons, no statistically significant trends were found.

1. INTRODUCTION

Precipitation is one of the main climatic elements which determines the availability of water resources and has considerable impact on different aspects of human activity. Knowledge of seasonal precipitation characteristics can bring further understanding of peculiarities of precipitation regime in a region of interest. The scientific works (Hulme et al., 1998) show that there are opposite trends in precipitation variability in northern Europe (wetting) and southern Europe (drying).

Seasonal precipitation in Romania has been investigated in connection with the large-scale circulation patterns (Busuioc and von Storch, 1996; Rimbu et al, 2001; Tomozeiu et al, 2005) It was shown that some types of atmospheric circulation, large scale mechanisms such as the North Atlantic Oscilation and El Niño-Southern Oscillation can be responsible for the anomalies in precipitation regime over the Romanian territory and, implicitly, can impact on the Danube River flow in its lower basin (Rimbu et al. 2002; 2004). Records of temperature and precipitation anomalies in Romania during the recent years have been analyzed in the context of corresponding extremes since the begining of the 20th century (Busuioc et al. , 2007) and the results show that the frequency and the magnitude of extreme events have increased both for temperature and precipitation in the last decades (Busuioc et al. 2003; 2007).

The Balkan Peninsula is characterized by general decreasing trends of precipitation beginning with the 1980s (Alexandrov, 2004). As it is an important issue, variability in Bulgaria's precipitation regime has been studied by many authors (Topliiski, 2002, 2005, Zlatunova and Penkov, 2002, Vekilska and Rathcev, 2000). There are several publications dedicated to precipitation variability across the Danubian Plain (Koleva, 1995; Nikolova and Vassilev, 2006; Petkova at all., 2008).

Though many publications on trends and seasonality of precipitation in Europe put the Balkan region and the south-eastern Europe in the context of global changes (Zveryaev, 2004), an in depth statistical analysis is needed in order to get more insight into the precipitation regime in our region in the context of contemporary climate change. The aim of this paper is to provide detailed information about the characteristics of annual and seasonal variability of precipitation in the Danube River lower basin, focusing on annual cycle and linear trends.

2. DATA AND METHODS

The present analysis is based on monthly precipitation totals from 22 meteorological stations situated in the Danube River lower basin both in Romania and Bulgaria. Data for Romanian stations are provided by the National Meteorological Administration, Romania. Data for Bulgarian stations have been compiled from the meteorological yearbooks published by the National Institute of Meteorology and Hydrology, Sofia, Bulgaria, from the Statistical Yearbook of the National Statistical Institute in Bulgaria and from the bulletins issued by Bulgaria's Executive Environmental Agency. The geographical coordinates of the stations are presented in Table 1. The stations have been divided into three groups according to their geographical distribution and the peculiarities of the study area as follows: 1) western part of the domain which includes the stations: Tr. Severin, Calafat, Băileşti, Bechet, Caracal, Tr. Măgurele, Vidin, Vratsa, Lom, Oryahovo, Kneja and Pleven; 2) central part of the domain including the following stations: Alexandria, Giurgiu, Obraztsov Chiflik, Razgrad, Bucuresti Băneasa and Călăraşi and 3) north-eastern part of the domain including the stations: Sulina, Tulcea, Galaţi and Hârşova.

The investigated period is 1961-2007. To reveal the characteristics of temporal precipitation variability, two reference periods have been considered: 1961-1990, which is named *baseline climate* by the World Meteorological Organization and the last 30 years (1978 – 2007), referred to as *recent climate*.

Table 1. Geographical coordinates of the meteorological stations considered in the present study.

	Station name	Lat;	Lon	Altitude	Country
1.	Tr. Severin	44º 38’	22º 38’	77	RO
2.	Calafat	43º 59’	22º 57’	61	RO
3.	Baileşti	44º 01’	23º 20’	57	RO
4.	Bechet	43º 47’	23º 57’	36	RO
5.	Caracal	44º 06’	24º 22’	106	RO
6.	Tr. Măgurele	43º 45’	24º 53’	31	RO
7.	Vidin	43° 39'	22° 53'	37	BG
8.	Vratsa	43° 12'	23°32	548	BG
9.	Lom	43° 49'	23° 14'	21	BG
10.	Oryahovo	43° 44	23° 58	31	BG
11.	Kneja	43° 30'	24° 05'	120	BG
12.	Pleven	43° 25'	24° 35'	133	BG
13.	Alexandria	43º 59’	25º 21’	75	RO
14.	Giurgiu	43º 53’	25º 57’	24	RO
15.	Obraztsov chiflik	43° 48’	26° 02’	153	BG
16.	Razgrad	43° 32'	26° 31'	183	BG
17.	Bucharest-Băneasa	44º 30’	26º 08’	90	RO
18.	Călăraşi	44º 12’	27º 21’	19	RO
19.	Sulina	45º 10’	29º 44’	3	RO
20.	Tulcea	45º 11’	28º 49’	4	RO
21.	Galaţi	45º 29’	28º 02’	69	RO
22.	Hârşova	44º 41’	27º 57’	38	RO

To obtain the most reliable results the quality of initial data has been verified. The data have been checked for missing values and have been tested for homogeneity. There are not missing values in the investigated time series.

A homogeneous time series is defined as one in which trend and variability are not influenced by artificial factors such as relocation or environmental changes around the station, changes of instruments or of the observation methods (Keiser and Griffiths, 1997; Sneyers, 1975).

The AnClim software (http://www.climahom.eu/AnClim.html) has been used to test the homogeneity of monthly precipitation with the Alexandersson test (Alexandersson and Moberg, 1997). Non-homogeneities (referred to afterwards as breakpoints) have been detected mainly after the 80s. For the Bulgarian stations this may be due to the different data sources.

The distribution of breakpoints along the months of a year (Figure 1) shows that the maximum number of stations (9) have been detected in April. At 5 stations break points have been detected in June and at 4 stations in March, May and July, respectively.

All the series of monthly precipitation totals where breakpoints were detected have been adjusted with the AnClim software. After the homogenization of monthly precipitation totals the seasonal and annual totals have been calculated. The seasons are determined as follows: winter – December, January, February; spring – March, April, May; summer – June, July, August and Autumn – September, October, November.

In order to determine the trend of series of seasonal and annual precipitation totals, linear regressions have been used.

precipitation amount in summer months can be associated with convective precipitation that is usually observed in this season. In general, the monthly

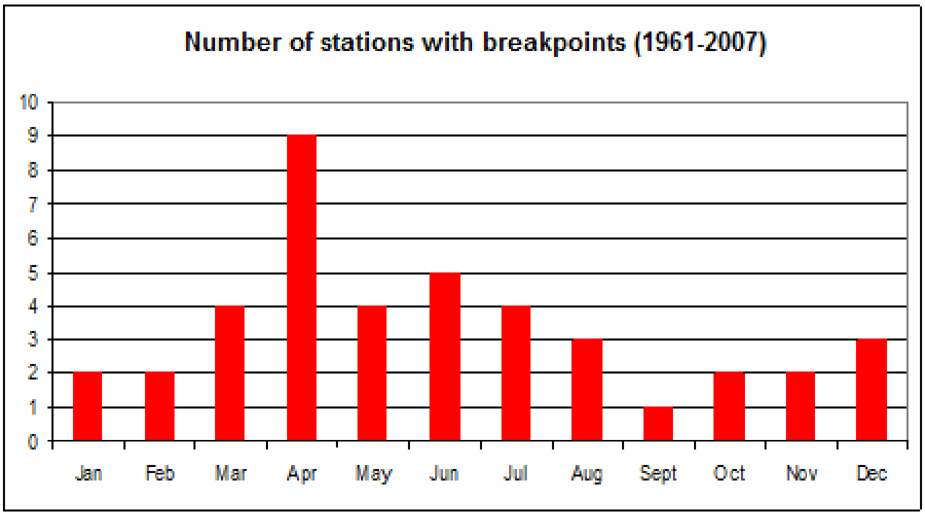

Fig. 1. Number of stations with breakpoints during a year over 1961-2007.

3. RESULTS

3.1. Annual cycle

The analysis of the results for the Romanian and Bulgarian meteorological stations considered together for the entire domain revealed that the highest monthly average in the annual cycle of precipitation was, in general, recorded in June but at some stations the rainiest month is May or July, with some differences between the two periods. During the 1961-1990 time period the analysis shows an important concentration of the highest monthly averages in June. The 1978 – 2007 period does not display the same stability feature for June. The maximum values are distributed almost evenly over May, June and July. The monthly minimum precipitation is mainly recorded in February and October. (Figure 2, an example for some stations). The highest precipitation amounts over 1978-2007 are lower than those for the reference period 1961-1990, except for the autumn months (September, October, November).

The distribution of the highest and lowest monthly averages was analyzed for each subgroup of stations in order to determine the general and regional characteristics of the wettest and driest months.

The analysis reveals different characteristics of the annual cycle for each subgroup and some differences between the two sub-periods. During 1961-1990, the wettest month is June for the western and central subgroups, while for the eastern one, the wettest month is May. This characteristic changed in the second period (1971-2007), since the wettest month on record was as follows: May-western subgroup, July-central subgroup and June- eastern subgroup (Figure 3).

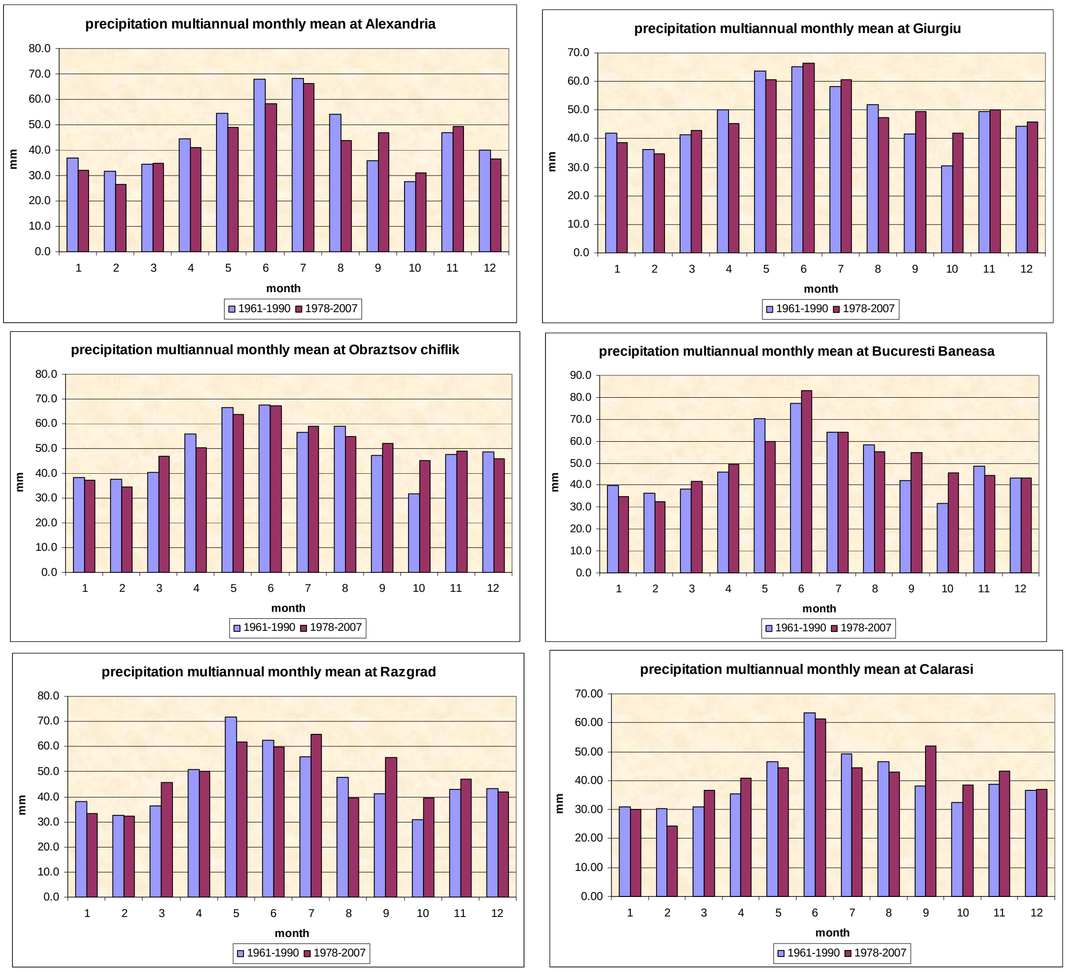

Fig. 2. Annual cycle of monthly precipitation totals for the group of stations located in the central part of the Danube River lower basin. Comparison between the periods 1961-1990 and 1978-2007.

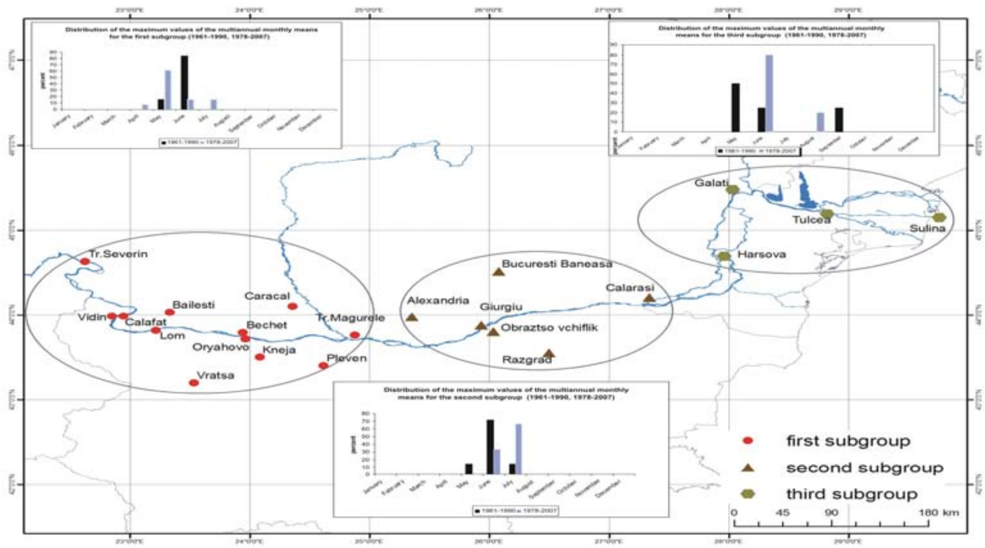

Fig. 3. Distribution of the highest monthly precipitation averages for 1961-1990 (left column) and 1978 – 2007 (right column) with time periods for each subgroup.

Regarding the driest month over the 1961-1990 period, records showed it to be September –western subgroup, October-central subgroup and an even distribution between March and October-eastern subgroup. Over 1971-2007, the driest month on records is February for each subgroup (Figure 4).

summer precipitation has the main contribution in the annual precipitation totals (Clima Romaniei, 2008). The summer precipitation amount accounts for about 30% of the annual precipitation (Figure 5). The spring precipitation total contributes with about 25% to the annual precipitation and the winter precipitation

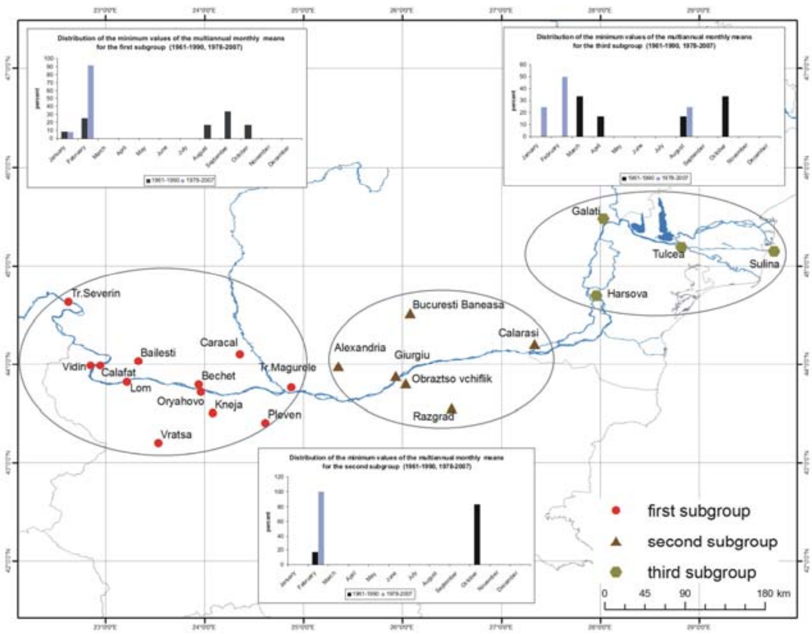

Fig. 4. Distribution of the lowest monthly precipitation averages over 1961-1990 and 1978 – 2007 for each subgroup.

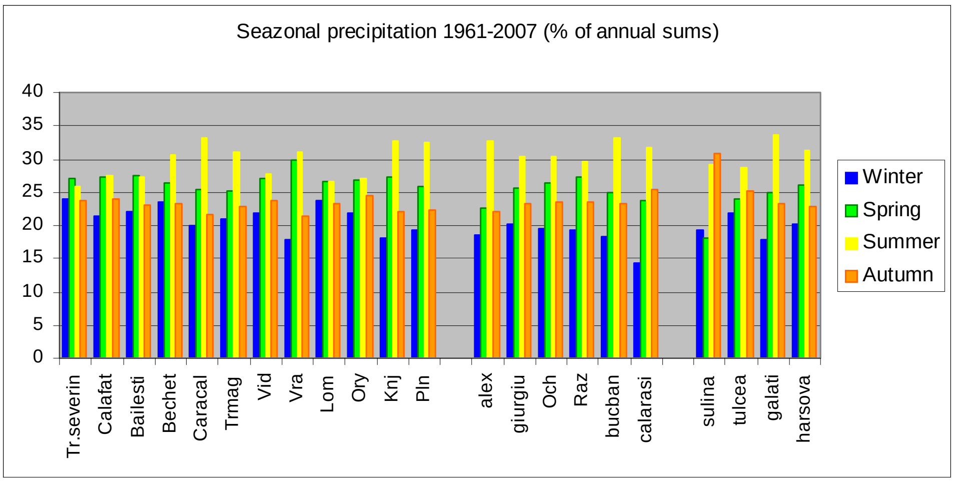

Fig. 5. Seasonal distribution of precipitation totals (% of annual values) for each subgroup.

Comparisons between seasonal and annual precipitation amounts over the entire period 1961-2007, show that total accounts for about 20% and even less of the annual total.

3.2. Trends

An analysis of the linear trend over 1961-2007 pointed out some characteristics of the precipitation regime for our region of interest (Table 2).

A decreasing trend in winter precipitation is statistically significant for some of the stations from the western and eastern groups (Table 2).

In spring and summer the trend is not statistically significant (not shown). For autumn (Table 2), a slightly positive trend has been identified, mainly due to the increase occurred after 1978, but statistically significant only for two stations in the central subgroup.

At most of the investigated stations a decreasing trend (but not statistically significant) in annual precipitation totals has been detected over 1961-2007. Only six stations in the central subgroup (Alexandria, Giurgiu, Bucharest-Baneasa, Obraztsov chiflik, Razgrad and Calarasi) show an increasing (not statistically significant) trend (Table 2).

The results presented above show that decadal variability is the most important characteristic of the precipitation amount in the analyzed area. This result is in agreement with that presented by Busuioc et al. (2010) in a study covering the entire Romania.

4. CONCLUSIONS

In general, the annual cycle of precipitation, showed that June is (as) the wettest month and February and October

Table 2. Linear trend of winter, autumn and annual precipitation (mm/10 years) over 1961-2007. The values marked with asterisk are statistically significant at significant level p <0 .05.

	winter	autumn	annual
Tr. Severin	-13.5	-3.1	-24.1
Calafat	-8.4	7.8	2.5
Baileşti	-12.6*	6.6	-2.7
Bechet	-31.8*	1.4	-4.6
Caracal	-14.4*	6.5	-15.6
Tr. Măgurele	-12.9*	6.4	-13.9
Vidin	-5.9	3.6	-9.3
Vratsa	-10.1*	1.6	-12.3
Lom	-9.5	8.5	-0.9
Oryahovo	-9.2	-1.6	-12.8
Kneja	-6.9	1.0	-8.5
Pleven	-12.0*	4.5	-6.7
Alexandria	-5.6	12.2	11.0
Giurgiu	-4.8	13.5	5.5
Obraztsov chiflik	-5.9	13.0	6.2
Razgrad	-4.5	16.6*	7.0
Bucharest - Băneasa	-7.5	15.8	6.1
Călăraşi	24.5	15.6*	11.1
Sulina	-8.3*	9.5	5.2
Tulcea	-13.6*	2.1	-6.9
Galaţi	-10.5*	8.3	5.4
Hârşova	-14.0*	-2.1	-22.0

the driest ones, with some changes for the two analysed sub-periods and the three regional subgroups. The analysis over the entire considered area showed some particularities for each 30-year period:

– the wettest month is very well represented by June for the1961-1990 time period;
– the driest month reaches more than 80% of the number of cases in February for the 1978 – 2007 time period.

However, a detailed analysis over the three subgroups revealed that, during 1961-1990, the wettest month is June for the western and central subgroups, while for the eastern one, the wettest month is May. For 1971-2007, the wettest month is recorded in May-western subgroup, July-central subgroup and June- eastern subgroup.

Regarding the driest month, for the 1961-1990 period, this is recorded in September –western subgroup, October-central subgroup and evenly distributed between March and October- eastern subgroup. For the period 1971-2007, the driest month is recorded in February for all subgroups.

As regards the seasonal characteristics, one of the most important findings is the identification of a decreasing trend in winter precipitation but statistically significant only at six stations. For other seasons, no statistically significant trends were found. This result shows that decadal variability is the most important characteristic of the precipitation amount in the analyzed area. This result is in agreement with that presented by Busuioc et al. (2010) in a study which covers the entire Romania.

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